

1 Introduction

The transition from fossil fuels to renewable energy requires the use of energy models to decide which technologies to invest into and when.

To increase their accuracy, models can also consider technical limitations of generators to ensure a plan is feasible in the real world.

Minimum up and down time (MU/MD) constraints model the fact that some types of generators cannot be started up or shut down in consecutive hours and are among the most used in such models [1].

The Tulipa Energy Model differs from other models in its ability to flexibly cluster variables together to reduce model size (Fig 1) but lacks these constraints.



Figure 1: Example of fully flexible temporal resolution, compared to uniform hourly resolution

[1] L. Montero, A. Bello, and J. Reneses, "A Review on the Unit Commitment Problem: Approaches, Techniques, and Resolution Methods," *Energies*, vol. 15, no. 4, p. 1296, Feb. 2022, doi: 10.3390/en15041296.

2 Research Question

How do minimum up/down time constraints with fully flexible temporal resolutions affect the optimal solution of the model, in terms of:

- Computation Time
- Optimal Solution Cost
- Investment Plan

3 Experimental Setup

Case Study

The case study used for the experiments is based on the countries of the European Union, with the addition of UK, Norway and Switzerland (Fig 2). The figure also shows the temporal resolutions used for the geographically decreasing (GD) case.

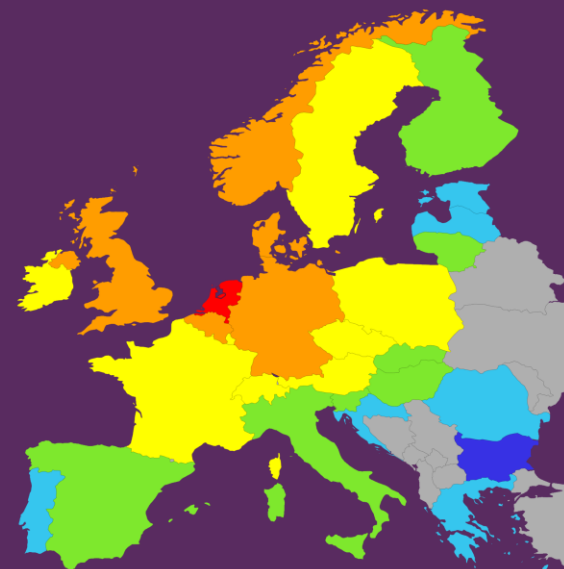


Figure 2: Countries modeled for the case study, and their resolutions for GD case

Temporal resolutions of different countries:
1hr: ■ 2hr: ■ 3hr: ■ 4hr: ■ 5hr: ■ 6hr: ■

Experiments

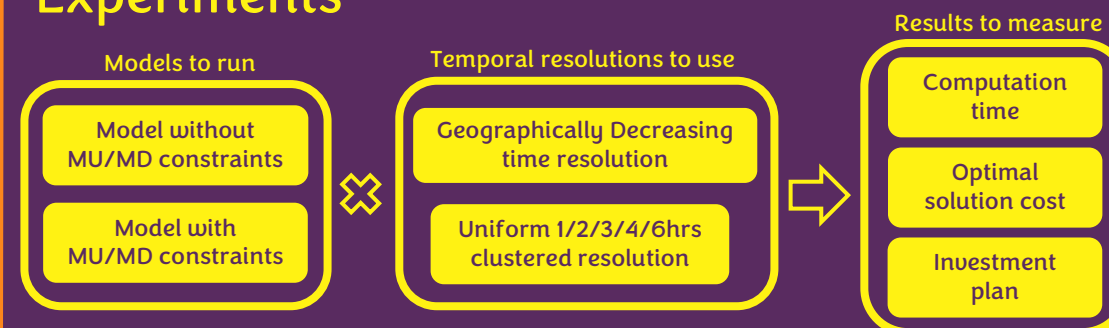


Figure 3: Experiment plan, with the models, temporal resolutions, and measured results

4 Results

The addition of MU/MD constraints improves the accuracy of the solution but also increases the runtime.

The geographically decreasing (GD) resolution exceeds the Pareto Front when only the cost for the target country (NL) is considered.

Investment plan changes are only significant for energy storage.

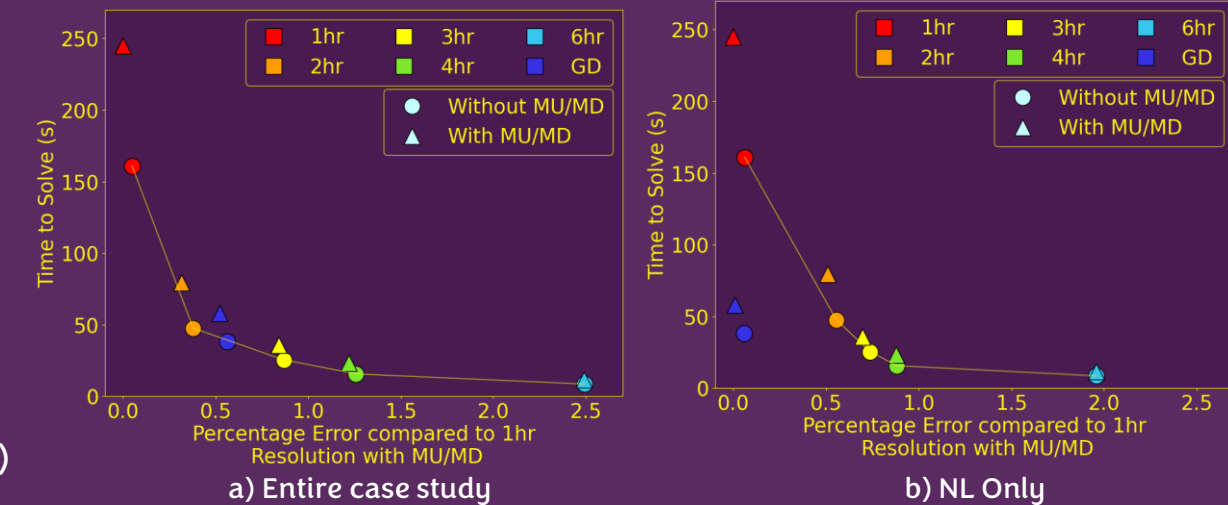


Figure 4: Model solving time against percentage error for the entire study and only NL

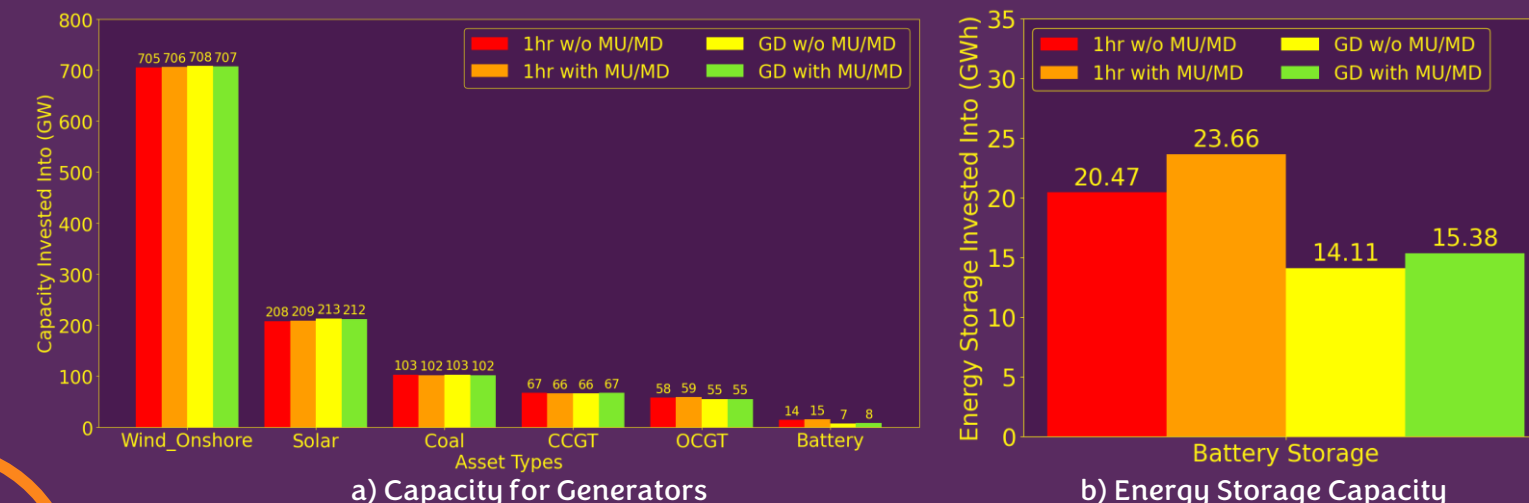


Figure 5: Investment plan for generators and for energy storage, considering 1hr and GD resolutions

5 Conclusions

1. The addition of MU/MD constraints increases the computation time.
2. MU/MD constraints have little effect on the optimal solution cost and the investment plan of generators, but a bigger effect on energy storage investments.
3. The benefit provided by fully flexible time resolutions in terms of the trade-off between computation time and solution accuracy is still present with MU/MD.